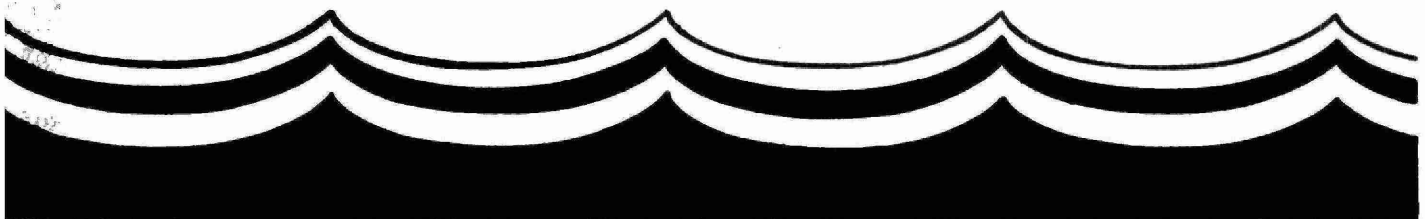


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STRATFORD / AVON RIVER  
**ENVIRONMENTAL  
MANAGEMENT  
PROJECT**



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STRATFORD/AVON RIVER ENVIRONMENTAL  
MANAGEMENT PROJECT

EXPERIMENTAL EFFORTS TO INJECT PURE OXYGEN  
INTO THE AVON RIVER

Technical Report S-4

by  
A. Bacchus & K. Willson  
Water Resources Branch  
Ontario Ministry of the Environment

June, 1983

## PREFACE

This report is one of a series of technical reports resulting from work undertaken as part of the Stratford-Avon River Environmental Management Project (S.A.R.E.M.P.).

This two year study was initiated in April 1980, at the request of the City of Stratford. The S.A.R.E.M.P. is funded entirely by the Ontario Ministry of the Environment. The purpose of the project is to provide a comprehensive water quality management strategy for the Avon River basin. In order to accomplish this, considerable investigation, monitoring and analysis has taken place. The outcome of these investigations and field demonstrations will be a documented strategy outlining the program and implementation mechanisms most effective in resolving the water quality problems now facing residents of the basin. The project is assessing urban, rural and in-stream management mechanisms for improving water quality.

This report results directly from the aforementioned investigations. It is meant to be technical in nature and not a statement of policy or program direction. Observations and conclusions are those of the authors and do not necessarily reflect the attitudes or philosophy of all agencies and individuals affiliated with the project. In certain cases the results presented are interim in nature and should not be taken as definitive until such time as additional data are collected.

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## ABSTRACT

As part of the Stratford-Avon River Environmental Management Project, the Southwestern Region of the Ontario Ministry of the Environment carried out a preliminary experiment in July, 1980 on the Avon River at reach 10-11. The purpose of this experiment was to investigate the viability of supplementing depressed night-time instream dissolved oxygen (DO) by injecting pure oxygen in the stream. Initial results were very encouraging and as a result a second experiment was planned to further investigate the technique.

The second experiment was carried out in July, 1981, by the Water Resources Branch of the Ontario Ministry of the Environment on the same river at reaches 9-10, 10-11, and 11-12. The purpose of this investigation was to determine the effectiveness of oxygenation and the total number of installations that would be required to achieve compliance with the Provincial Water Quality Objective for DO for the lower Avon River.

Data from this experiment were used to verify the one-dimensional stream DO model, DOMOD3, which was then used to simulate the effects of oxygenation under different conditions.

Experimental results indicate that the beneficial impacts of oxygenation range from 800 m to 1400 m downstream of the injection point; beneficial impacts are highly reach specific and depend on the physical, chemical, and biologic characteristics of the river. Modelling results indicate that at least 18 permanent installations would be required for a full-scale application of this technique to the lower Avon River. The capital cost of one installation is estimated at \$18,900 (1982 dollars) and operating and maintenance costs at \$1419 per month for five months per year.

The oxygen injection technique can therefore be used to supplement reduced instream DO levels although it may not be economically feasible in all cases. For the Avon River, the latter seems to be the case.

## ACKNOWLEDGEMENTS

The authors greatly appreciate the technical assistance provided by Mr. J. Goldman of CANOX Ltd. during the planning and instrument acquisition phases of this experiment. His assistance and moral support during the field experiment are also appreciated.

The success of this project was largely due to the co-operation and field assistance provided by Lorri Post and the summer students employed by the Ministry of the Environment, Southwestern Region and Water Resources Branch: Christine Hemrich, Jon M<sup>C</sup>Goey, Roger Brouillette, Louise Croteau, Monica Delange and Rick Butler.

The authors would also like to extend their appreciation to Dr. I. Heathcote and Messrs. M. Fortin, D. Weatherbe and D. Veal for their editing and constructive criticisms in reviewing this report.

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## 1. INTRODUCTION

The Avon River (Figure 1) is a warm, shallow, poorly shaded river with excessive growths of algae and aquatic plants which at times choke the river and upset the normal oxygen balance essential to support aquatic life. These algal growths are attributed to an enrichment of river water resulting from large inputs of nutrients from municipal and agricultural sources. Figure 2 shows a plot of a "worst-case" daily minimum DO profile for June 20, 1977, for Stations 6 to 12 on the Avon River downstream of the City of Stratford. From this plot, it can be seen that DO concentrations drop to almost anoxic conditions between Stations 7 and 8 and then start to recover just upstream of Station 10.

One of the objectives of the Stratford-Avon River Environmental Management Project (SAREMP) is to demonstrate cost-effective remedial measures and feasible management practices for improved stream water quality. There are several management practices available to correct depressed instream DO levels. One such practice assessed was the "high pressure sidestream" technique used for the oxygenation of river water.

Oxygen gas is only sparingly soluble in water, saturation being about 10 parts per million at ambient conditions. The high pressure sidestream technique, in which pure oxygen is rapidly dissolved in water with a utilization factor of more than 90 percent in a single pass, was developed by the British Oxygen Company (BOC) some years ago for wastewater treatment. This technique was later extended to experiments on flowing rivers to determine whether it could be used to counteract oxygen depletion and consequent fish kills caused by pollution spills in natural waters. Positive results were achieved in BOC trials.

In the summer of 1980, the Southwestern Region of the Ontario Ministry of the Environment carried out an experiment using this technique for a single reach (Station 10-Station 11, see Figure 1) on the Avon River. The purpose of the experiment was to investigate

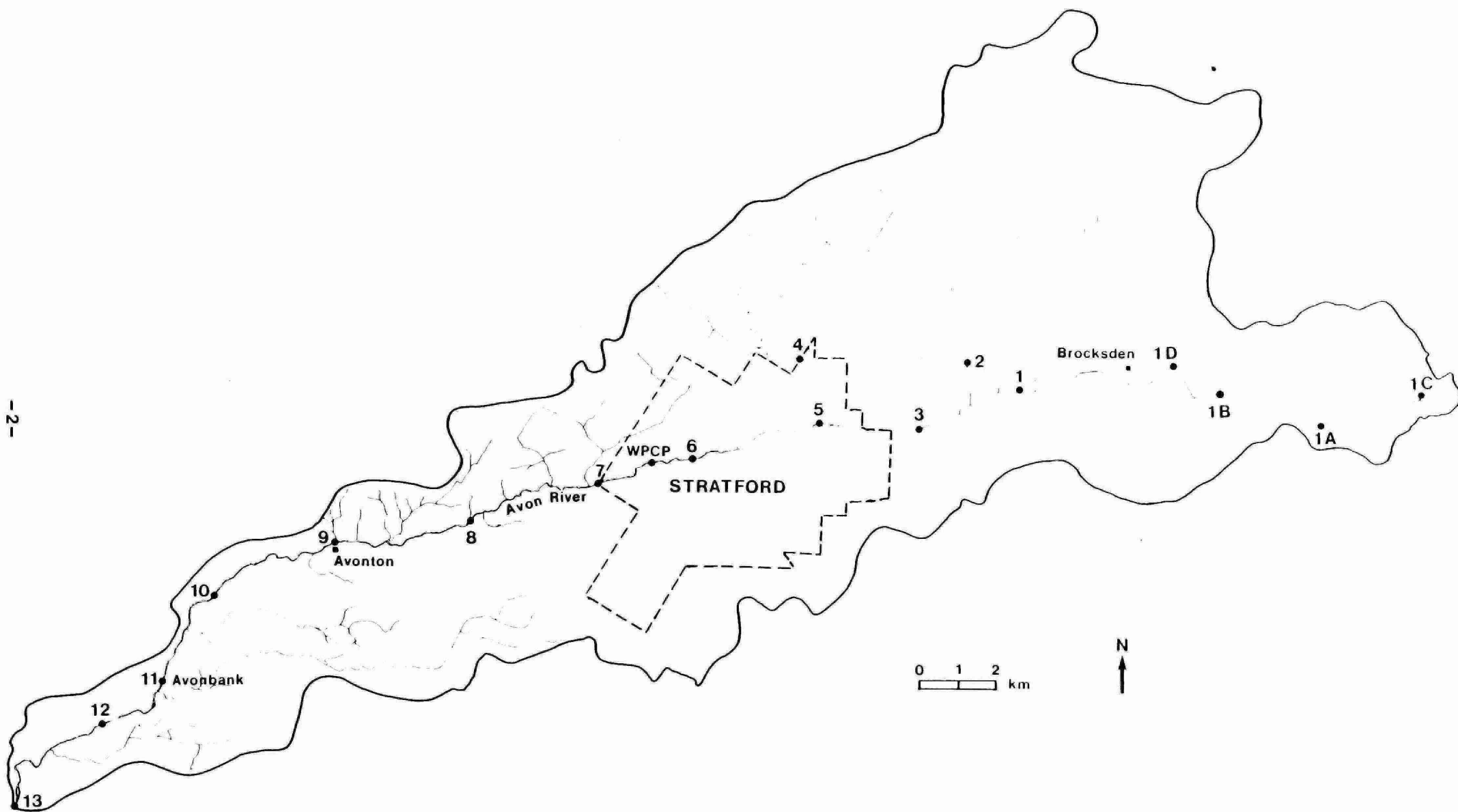


Figure 1 Monitoring Stations in the Avon River watershed

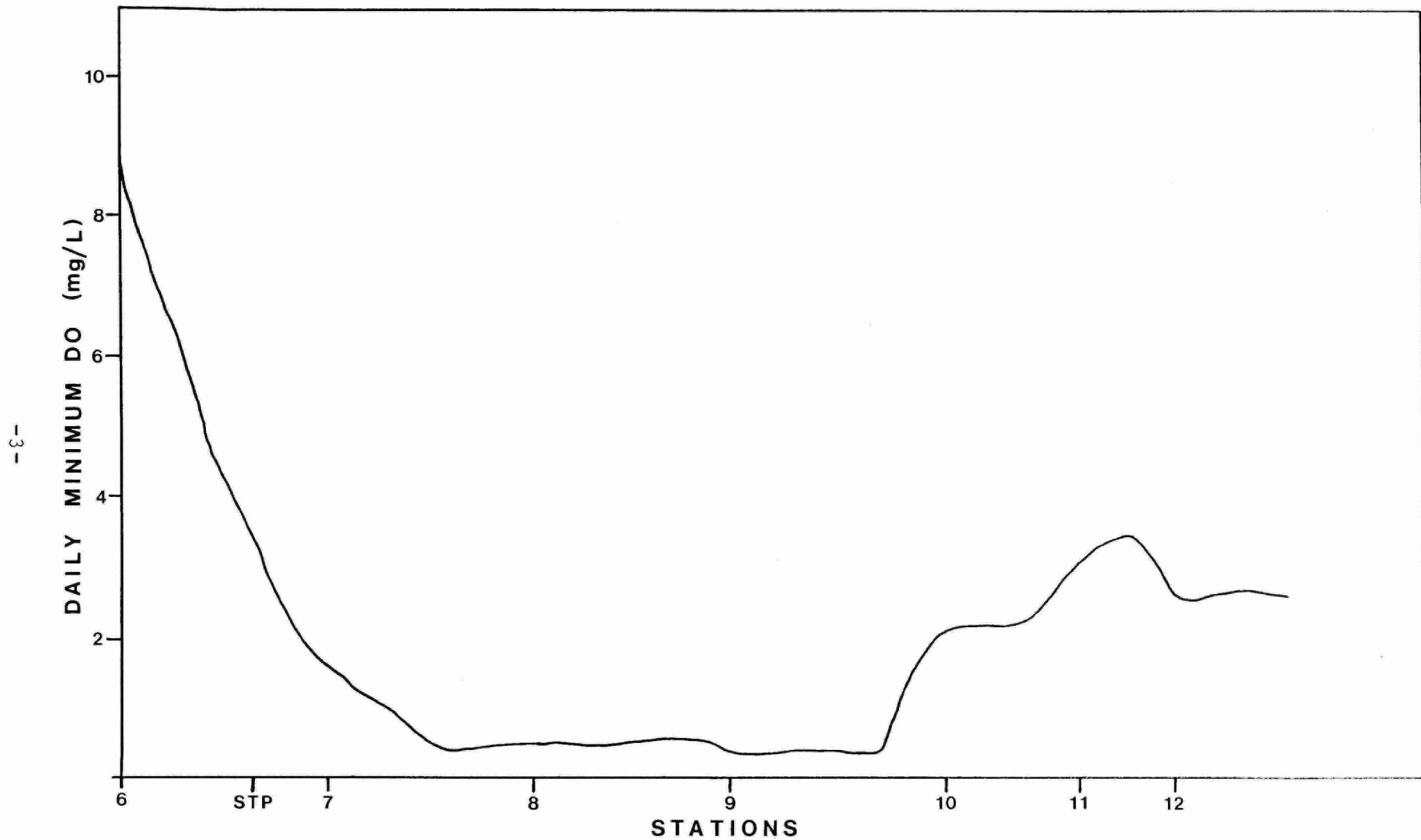


Figure 2: Plot of Daily Minimum Do Profile for Stations 6 to 12 for June 20, 1977.

(After: K. Willson, Avon River Instream Modelling, Technical Report S-9, January 1983, Draft)



the viability of this technique in supplementing night-time instream DO concentrations which were depressed as a result of aquatic plant respiration.<sup>1</sup>

In July, 1981, another more thorough investigation was carried out on the Avon River at Reaches<sup>\*</sup> 9-10, 10-11, and 11-12. The purpose of this second experiment was to determine the effectiveness of the technique in maintaining compliance with the Provincial Water Quality Objective (PWQO) of 47% of saturation (approx. 4 mg/L DO) and the total number of installations required when applied to the entire Avon River below the City of Stratford. This report presents the findings of the July, 1981 investigation.

1. Huber, D., Veal, D., and Goldman, J., "OXYGENATION OF THE AVON RIVER", Water and Pollution Control, Vol. 120, 1982, pp. 38-39.

<sup>\*</sup> A reach is defined as the length of stream between two stations, so "Reach 9-10" indicates the river reach between Stations 9 and 10.

## 2. DESCRIPTION OF STUDY AREA AND SITES

The sites chosen for the Avon River oxygen injection in July, 1981, were Stations 9, 10 and 11. Figure 1 is a basin map showing the location of these stations. Figures 3-5 show equipment set up on location at these stations. Sites were chosen principally for ease of access to the river and for satisfactory water depth for the positioning of diffusers.

The diffuser at Station 9 was located in mid-stream, approximately 50 metres downstream of the bridge on Perth County Road 19. Average water depth at the diffuser was 1.5 meters. Average depth for the reach from Station 9 to Station 10 was approximately 0.23 metres.

The diffuser at Station 10 was located in mid-stream, approximately 10 meters upstream of the bridge on Downie Township Sideroad 17. Average water depth at the diffuser was 1.5 meters. Average depth for the reach from Station 10 to Station 11 was approximately 0.23 meters.

The diffuser at Station 11 was located in mid-stream, approximately 150 meters upstream of the bridge on Downie Township Concession Rd. 10. Average water depth at the diffuser was approximately 0.7 meters. Average depth for the reach from Station 11 to Station 12 was approximately 0.17 meters.



Figure 3: Oxygen Injection Equipment at Station 9.

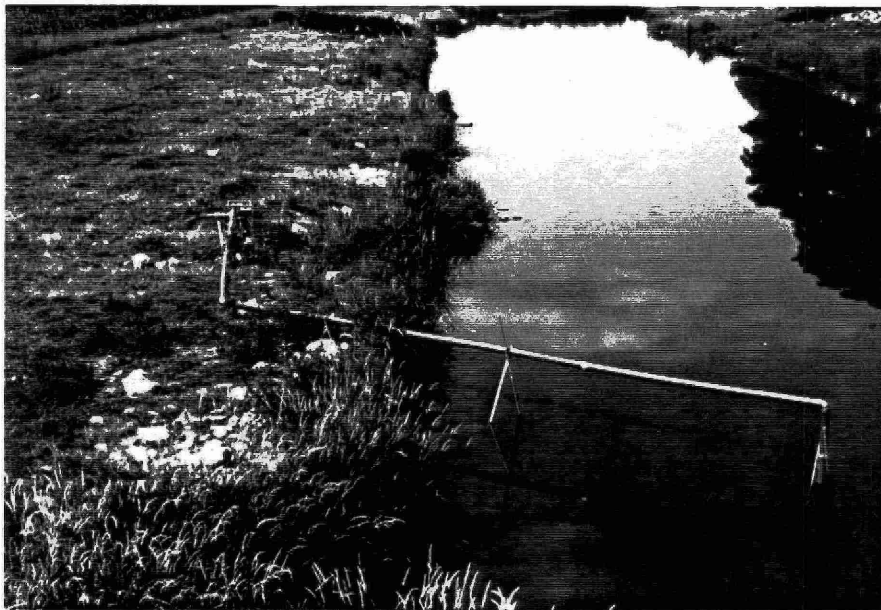


Figure 4: Oxygen Injection Equipment at Station 10.

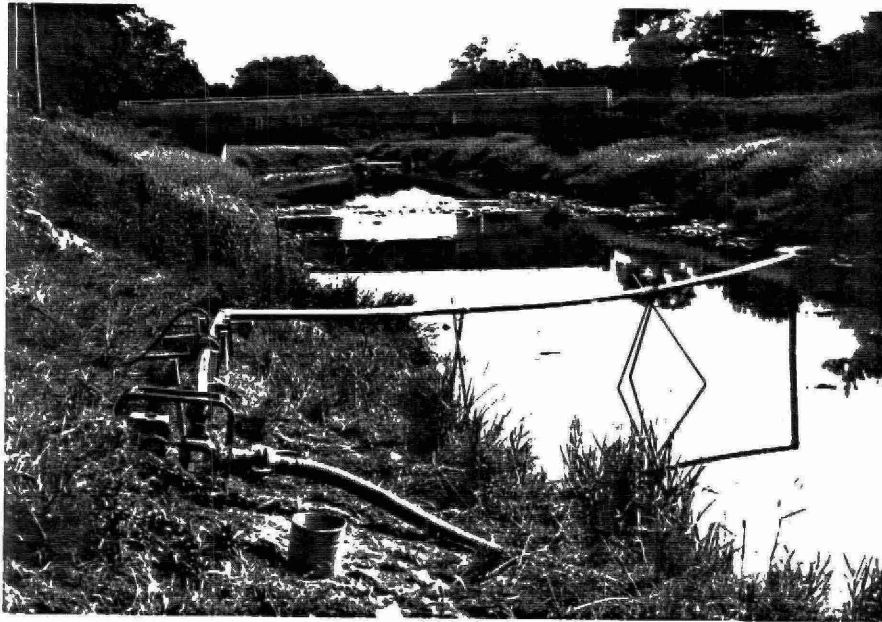


Figure 5: Oxygen Injection Equipment at Station 11.

### 3. EQUIPMENT AND METHOD

#### 3.1 Equipment

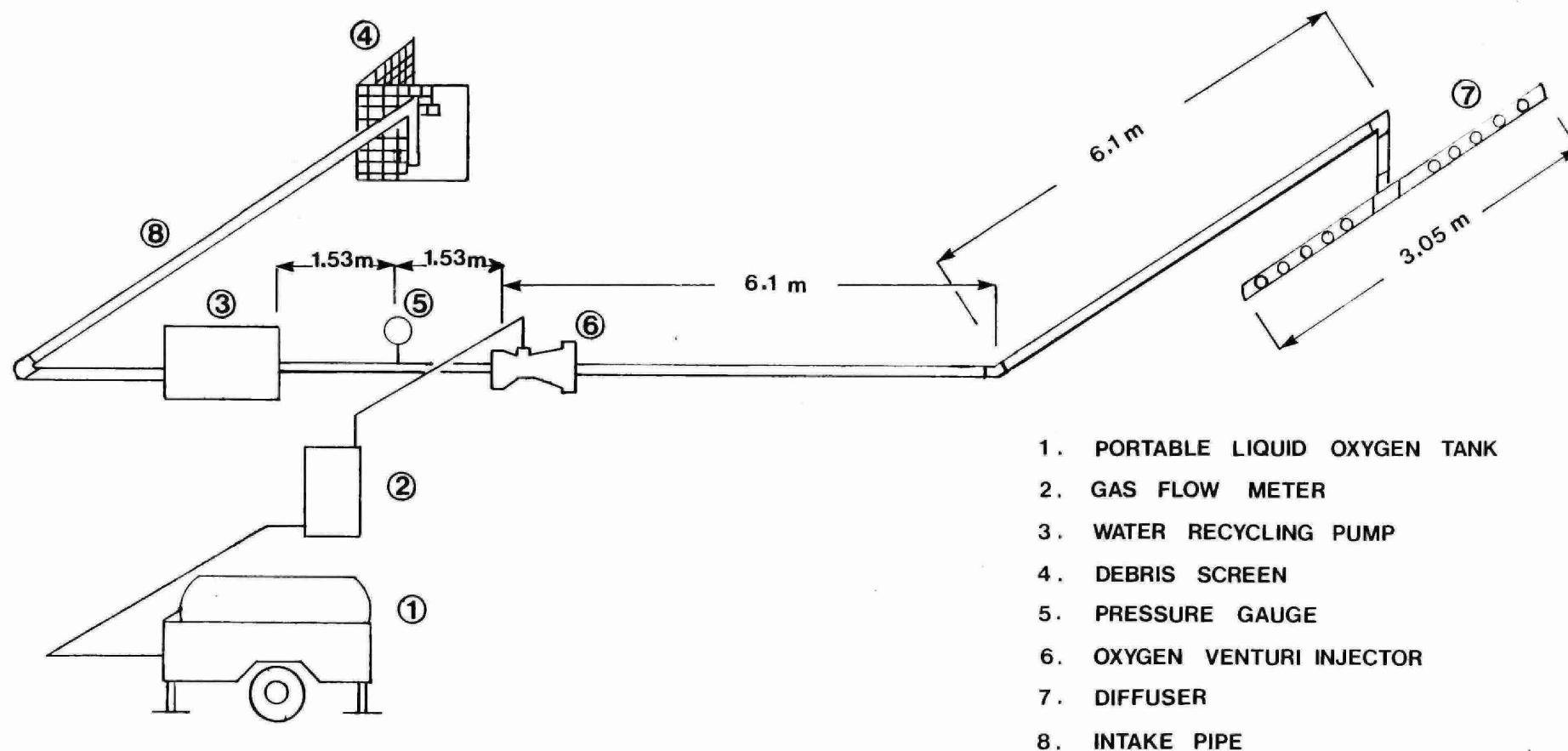
The injection equipment was prefabricated at the Ministry of the Environment Laboratory in Rexdale and transported to the sites. The sidestream water recycling system was constructed of 7.62 cm diameter UPVC pipe (see Figure 6 for a schematic diagram of the injection system). Pipe joint fittings were standard threaded galvanized fittings. The diffuser was 3.05 m long on a swivel joint and had 10-2.54 cm diameter holes drilled to facilitate flow of super-saturated water towards the bottom of the river and downstream (see Figures 7 and 8). A stainless steel oxygen venturi injector, designed and manufactured by Canox (see Figures 9 and 10), was connected 3.05 m from the discharge end of the pump using 7.62 cm x 19.05 cm galvanized flanges and gaskets. A Wisconsin 7460 Watts gasoline-powered 7.62 cm trash pump was used to take approximately one-tenth of the river flow, super-saturate it with oxygen and return it to the river via the diffuser (see Figure 11). The maximum pumping rate was given by the manufacturer as 1362 L/min. Pure oxygen was supplied by Canox from portable cryogenic containers, (see Figure 12) each with a capacity of 148 litres. Flow rates were regulated using a Canox-supplied gas flow meter (see Figure 13).

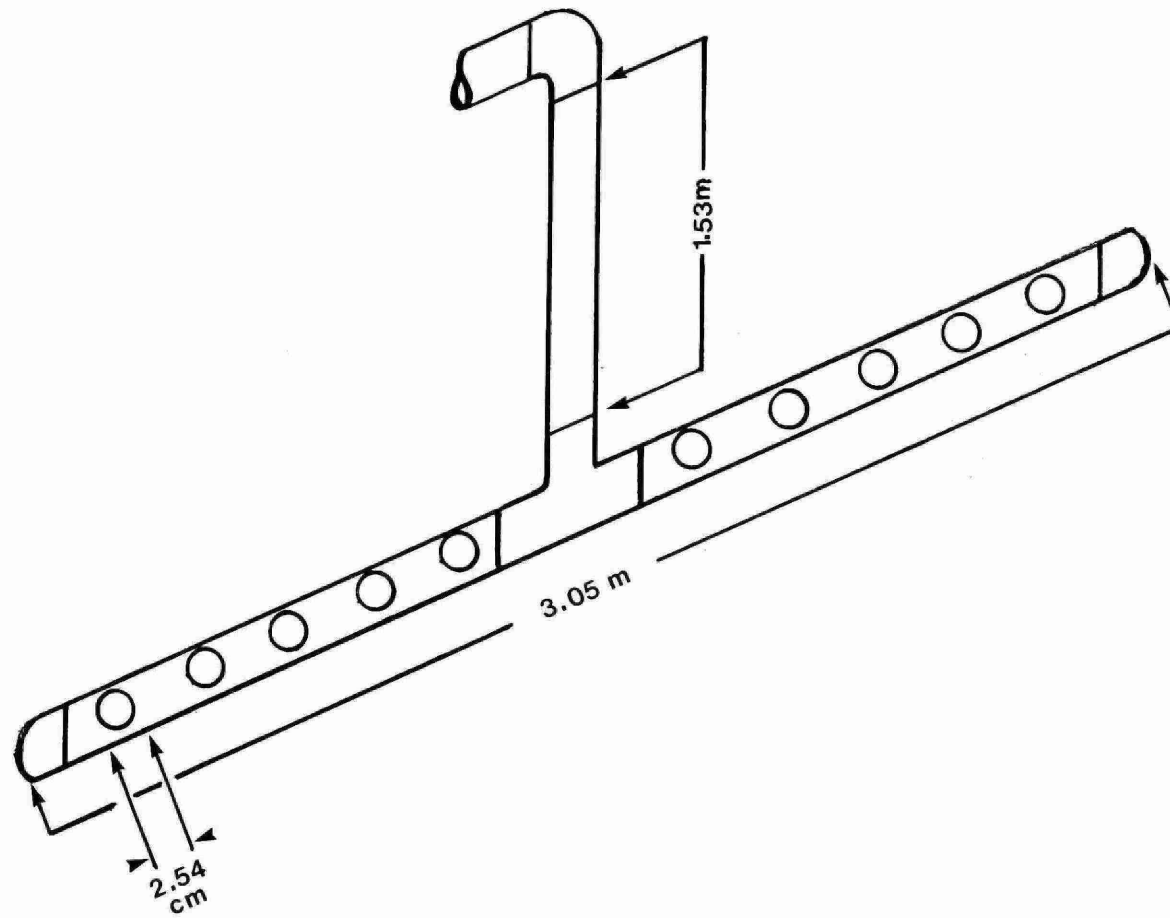
#### 3.2 Method

Before the experiment commenced, the three river reaches were staked at 100 m intervals. Electronic Instruments Ltd (EIL) oxygen-temperature meters connected to Rustrak recorders were installed 50 m upstream and downstream of the diffuser at each site. The upstream meters were placed as a control to record ambient DO and temperature conditions. A third meter was placed approximately mid-way between stations at each site.

**FIGURE 6: SCHEMATIC OF THE INJECTION SYSTEM**

(AFTER: JOSÉ GOLDMAN, CANOX LTD.)





**FIGURE 7 : DIFFUSER**

(AFTER: JOSÉ GOLDMAN, CANOX LTD.)

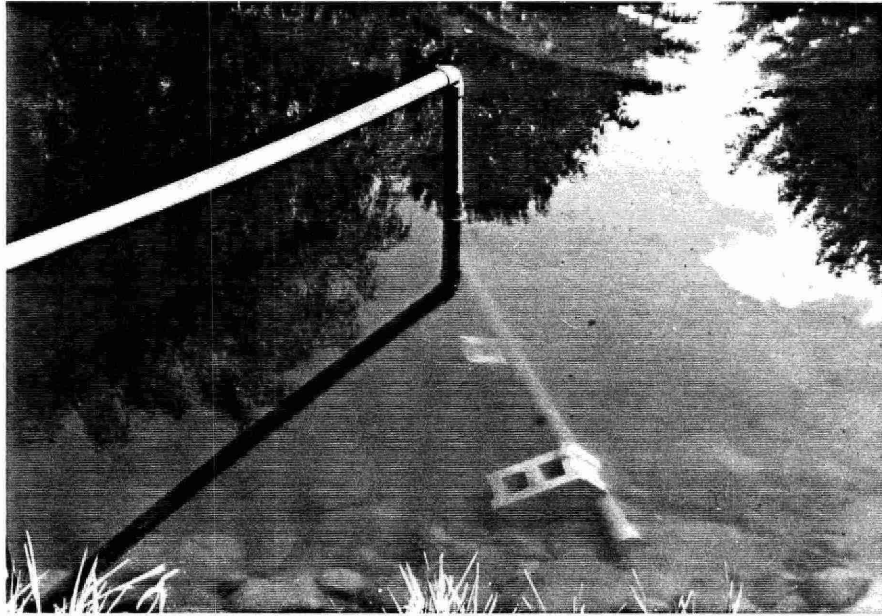
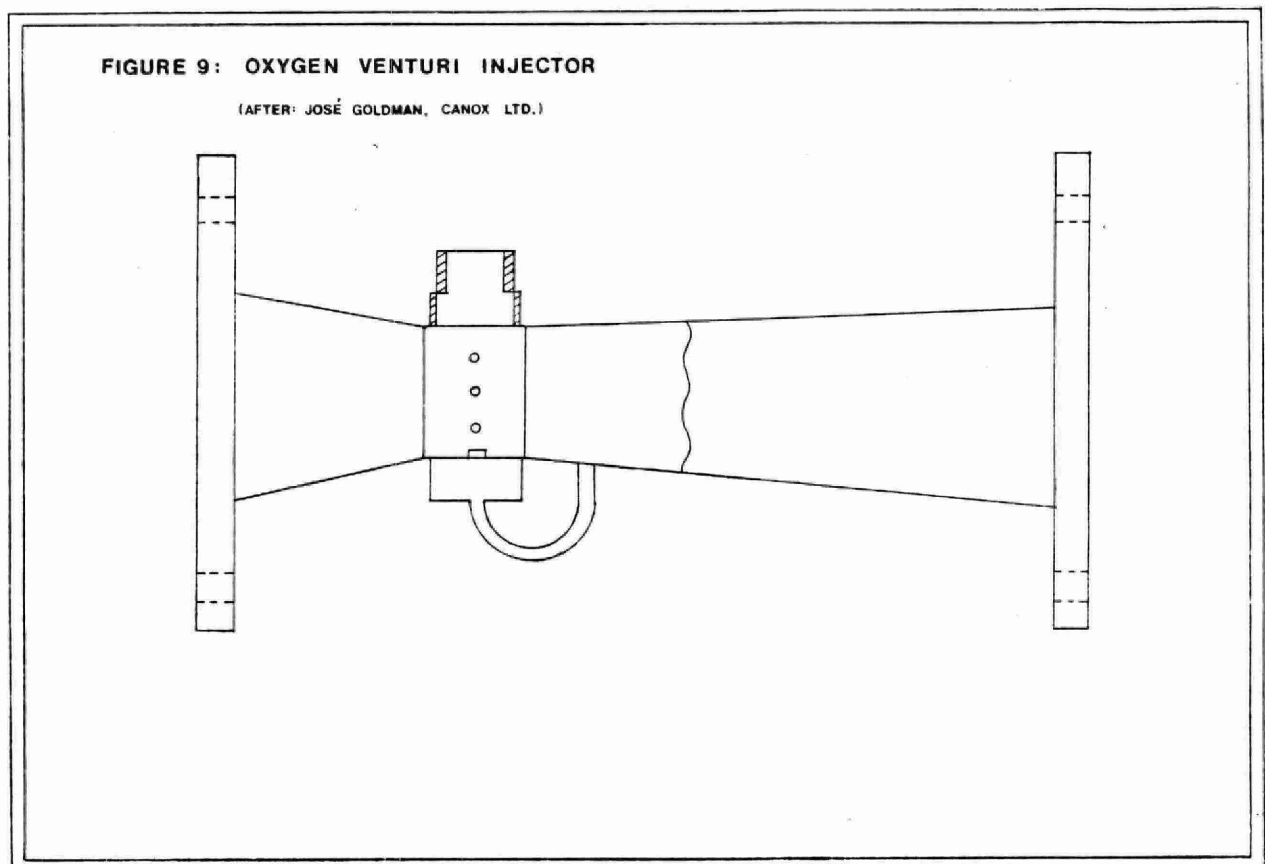


Figure 8: Diffuser





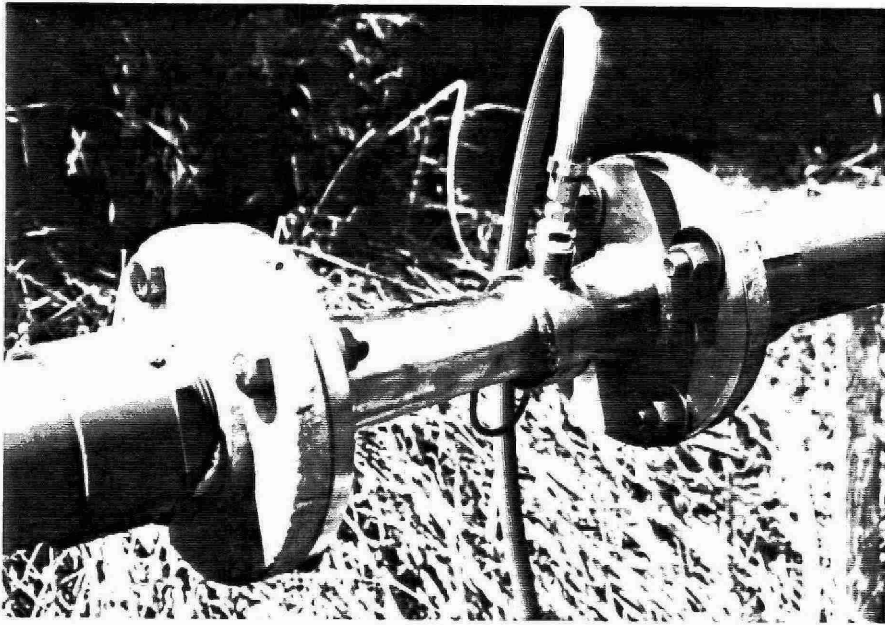


Figure 10: Oxygen Venturi Injector.

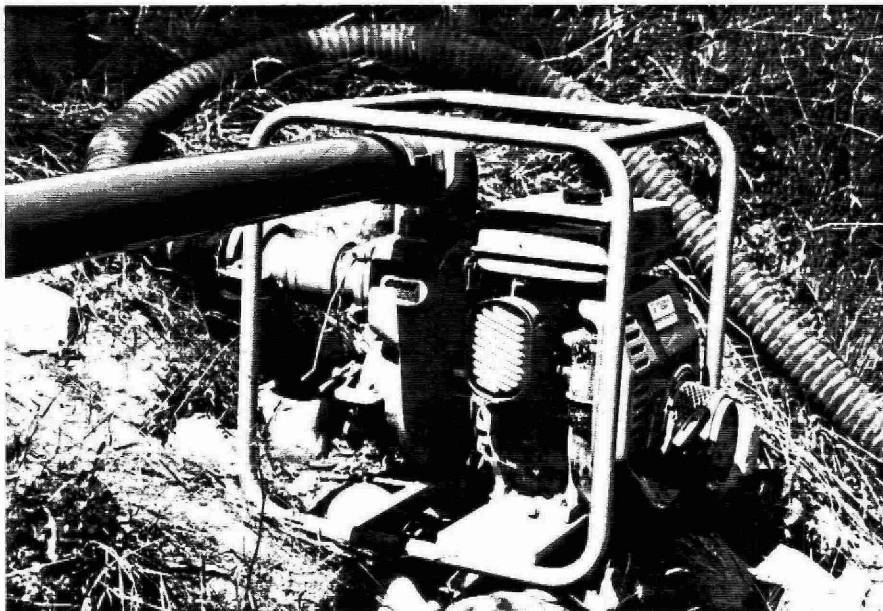


Figure 11: Pump.

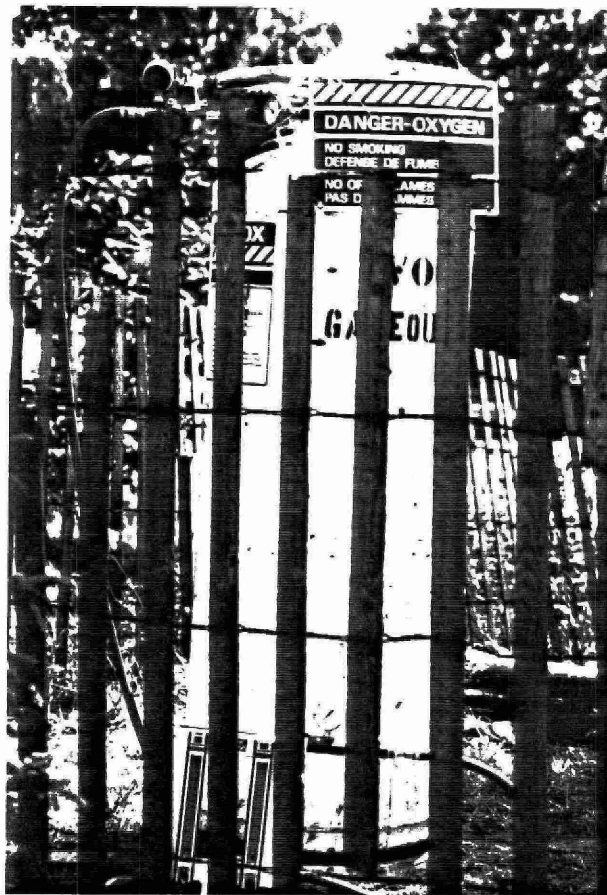


Figure 12: Cryogenic Container.

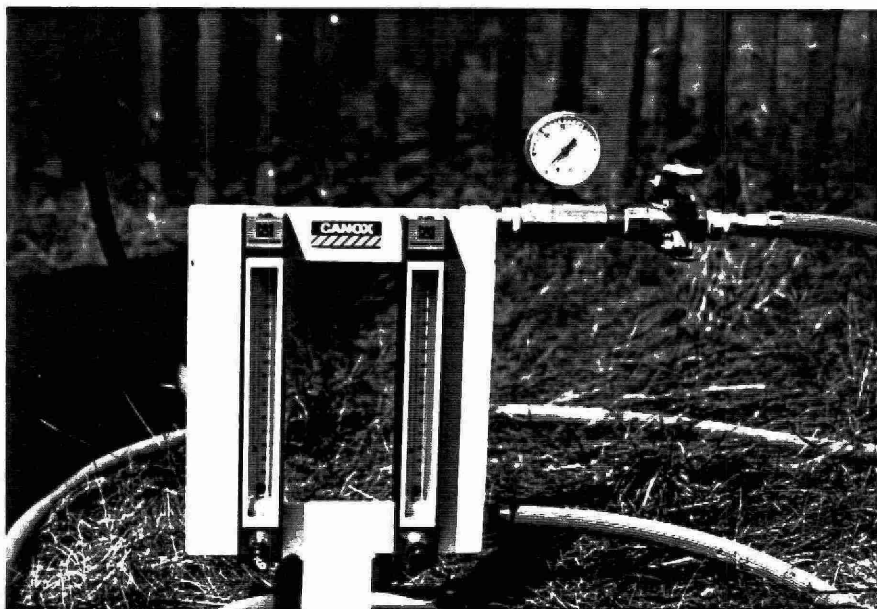


Figure 13: Gas Flow Meter.

The experiment was designed to commence when the instream DO concentration at the Station 9 control dropped to below 4 mg/L. To allow for the attainment of steady state conditions, crews waited one hour after the injection commenced before proceeding downstream to monitor DO and temperature at 100 m intervals. In doing this, the crews had to ensure that they did not overtake the leading edge of DO enriched water. Injection was stopped between 0600 hrs and 0730 hrs (sunrise).

Subsequent to these field measurements, the one-dimensional stream DO model, DOMOD3<sup>2</sup>, was calibrated and applied to the three reaches in an attempt to reproduce the observed profile data.

2. Ministry of the Environment. "Stream Water Quality Assessment Procedures Manual", Water Resources Branch, Toronto, D. Draper, Ed., 1980.

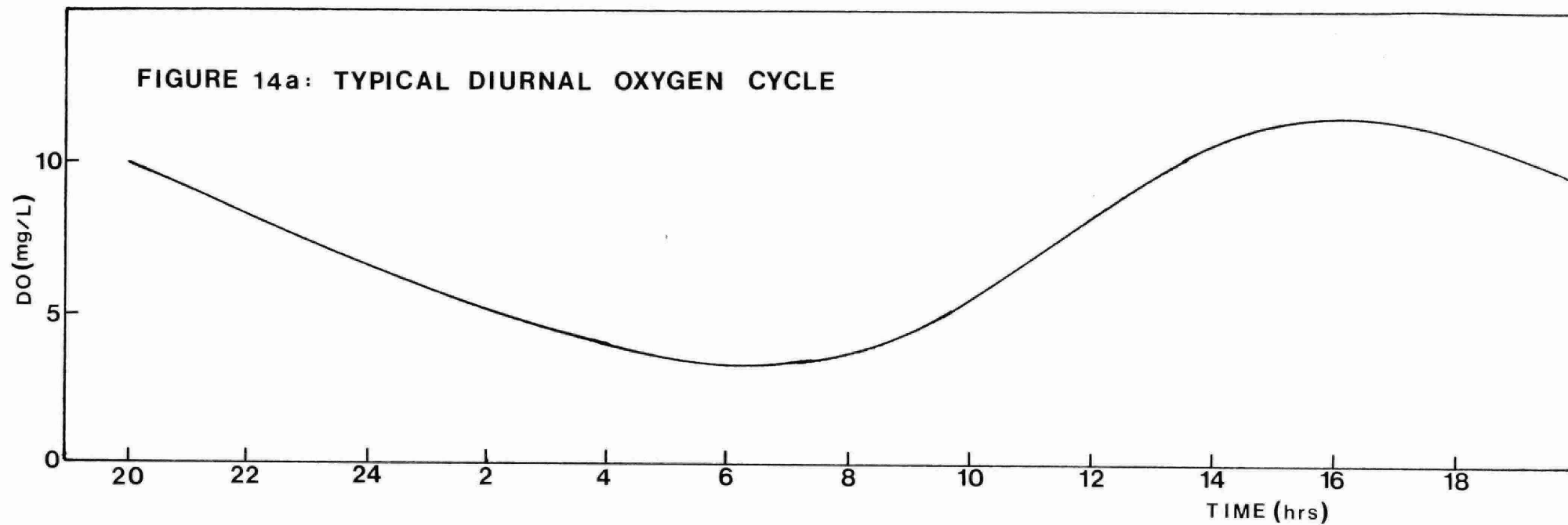
#### 4. RESULTS

Figure 14a shows a plot of a typical summer diurnal oxygen cycle for Station 9 (50 m downstream of the diffuser) prior to any experimental work. Figure 14b shows the change in the diurnal oxygen curve due to oxygenation on the night of July 21-22, 1981. From this figure, it can be seen that the experiment had a beneficial impact on the minimum DO values. It should be noted that the sag in the DO curve (Figure 14b) between 3:15 am and 4:00 am was due to a pump malfunction which required that injection equipment be shut off. This unplanned interruption in the experiment illustrates the rapid response of the river to oxygen injection.

Table 1 gives a summary of the experimental results at each station for each of the three nights. From this table, it can be seen that background DO concentrations varied with station location. For instance the difference between background DO concentration at all three stations was as much as 1.4 mg/L on the first night, 0.08 mg/L on the second night and 1.3 mg/L on the third night. Success in elevating the instream DO concentration was dependent on station location, with maximum increases ranging from 1.3 mg/L to 2.8 mg/L. At the end of the experiment, all stations exhibited a consistent drop in DO levels below pre-injection values (normal DO diurnal variation), with the exceptions of Station 9 on July 22-23, 1981 and Station 11, July 23-24, 1981; there is no apparent reason for these exceptions.

Figures 15, 16 and 17 illustrate the longitudinal extent of the stream oxygenation, based on the data collected at 100 meter intervals after equilibrium was achieved. There were several cases of suspected instrument malfunction; however, it was possible to correct many of the inconsistencies in the data using our best judgement. There were also several instances where upstream data had to be combined with downstream data (particularly temperature data) in order to produce a uniform set of data for a station. Two of the profiles (July 21-22 and July 22-23 for Station 10) were highly suspect and were discarded.

**FIGURE 14a: TYPICAL DIURNAL OXYGEN CYCLE**



**FIGURE 14b: TYPICAL DIURNAL OXYGEN CYCLE SHOWING EFFECTS OF OXYGEN INJECTION**

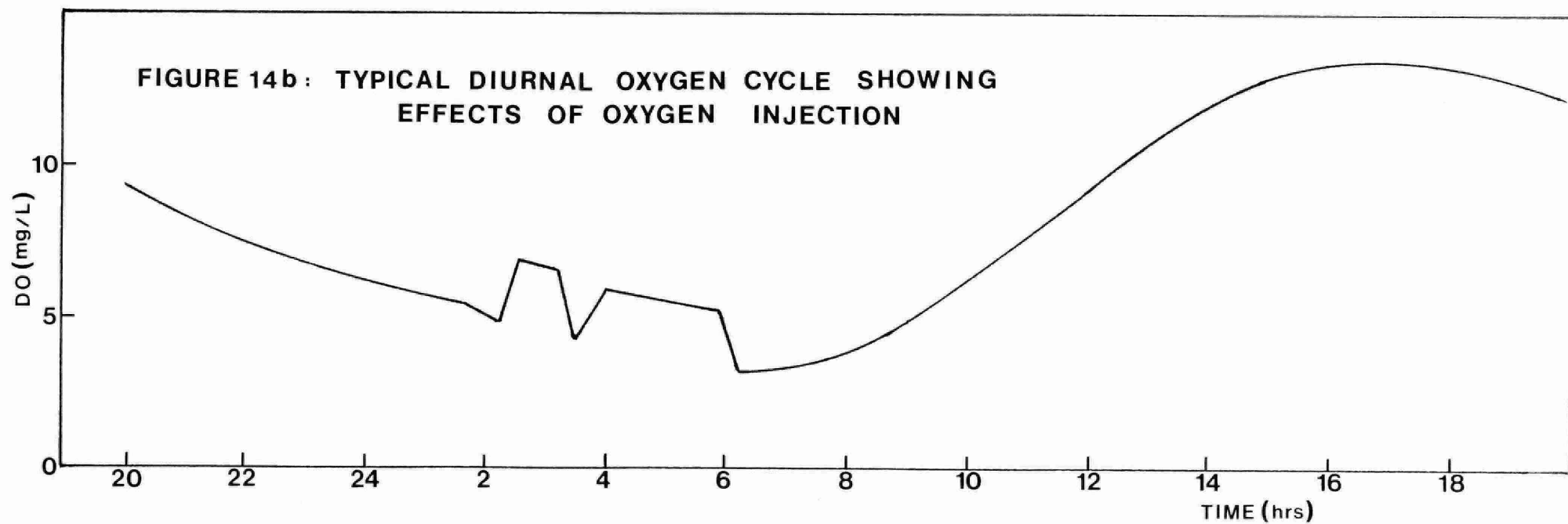


TABLE 1: SUMMARY OF EXPERIMENTAL RESULTS

Date	Stn.	Time at Start of Injection (am)	Background DO Before Start of Injection (mg/L)	Peak DO During Injection (mg/l)	Background DO at end of Injection (mg/L)	Longitudinal Extent of Oxygen Injection (m)
July						
21-22	9	02:15	4.9	6.8	3.3	1000
21-22	11	01:30	5.5	6.8	5.3	1400
22-23	9	01:15	5.8	8.6	5.6	1400
22-23	11	00:12	6.6	9.3	5.3	1400
23-24	9	01:00	6.6	8.4	5.6	800
23-24	10	01:00	5.3	7.9	4.0	1200
23-24	11	02:30	5.5	7.7	5.4	1400

FIGURE 15: LONGITUDINAL EXTENT OF OXYGENATION FOR REACH 9-10

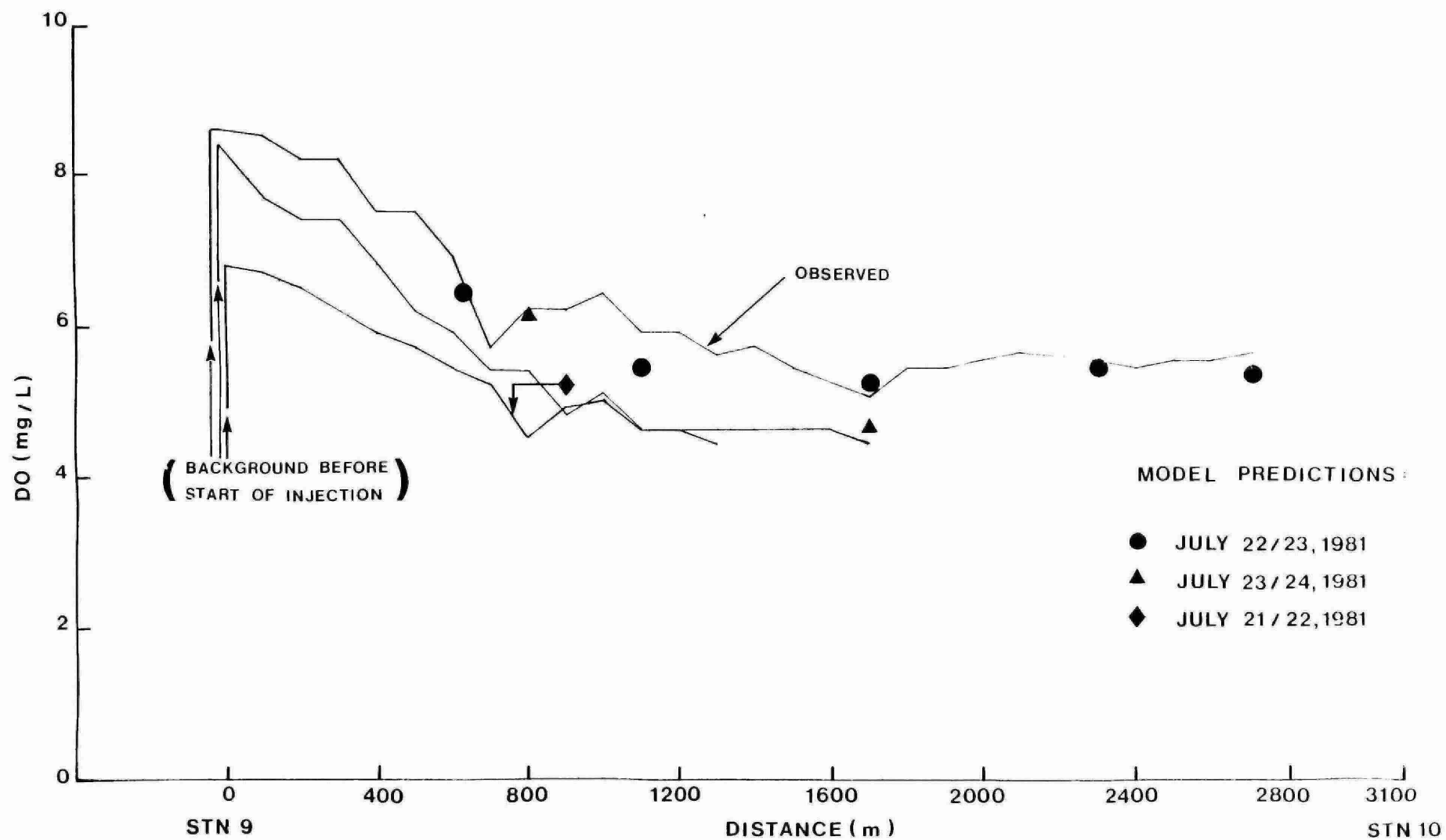


FIGURE 16: LONGITUDINAL EXTENT OF OXYGENATION FOR REACH 10-11

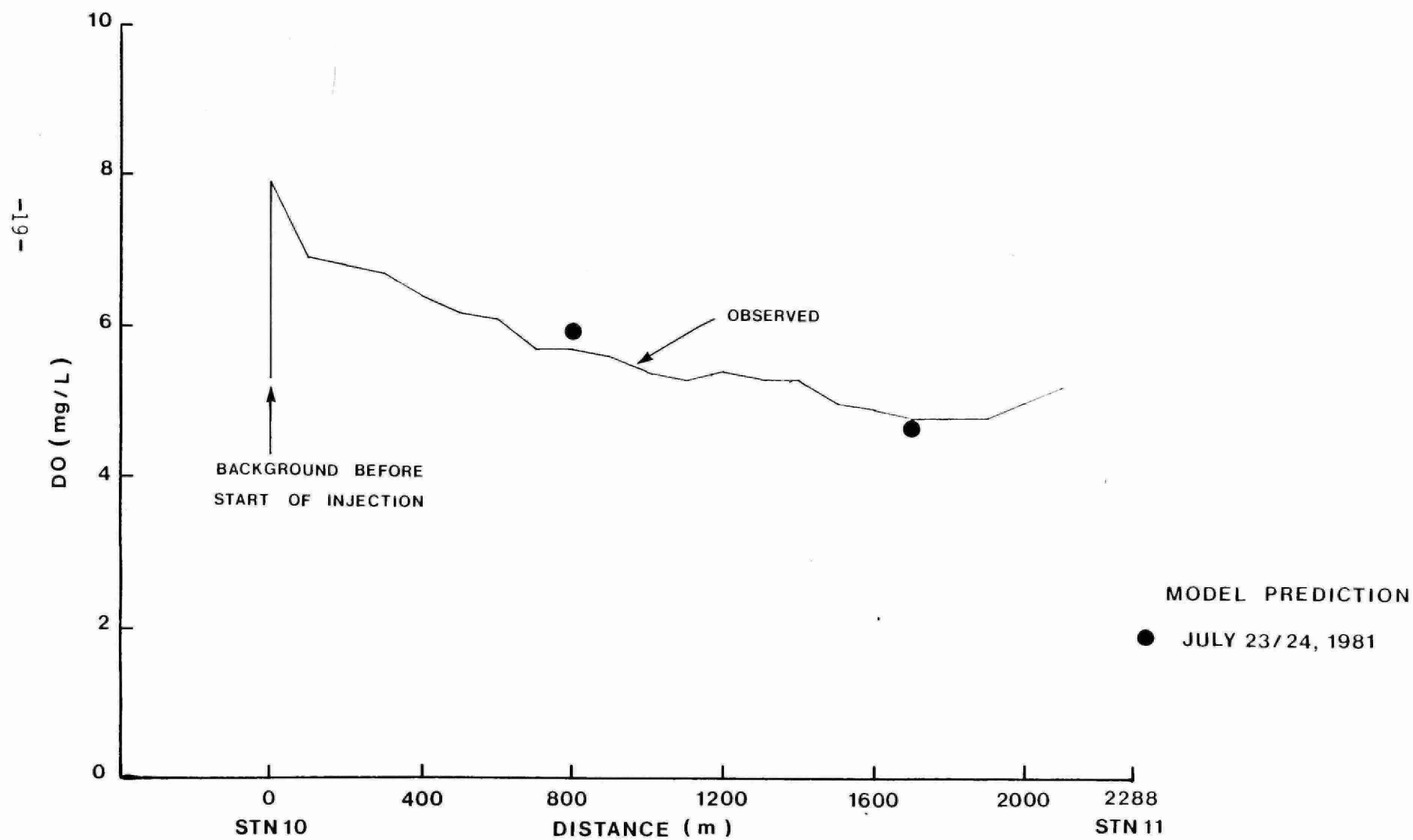
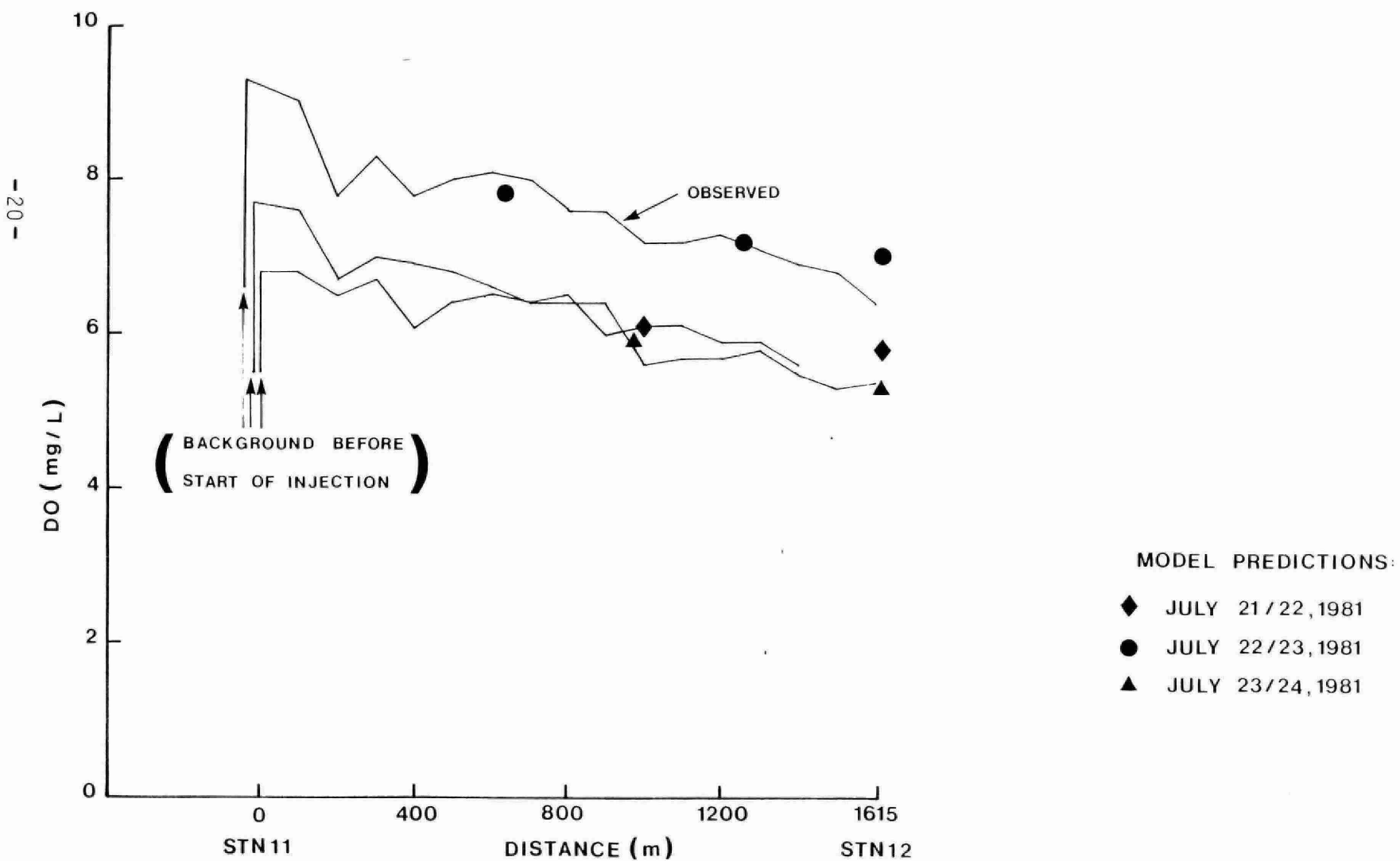




FIGURE 17: LONGITUDINAL EXTENT OF OXYGENATION FOR REACH 11-12



The instream DO concentration in Reach 9-10 returned to background level approximately 1000 m downstream of the injection point on the first night, 1400 m on the second night and 800 m on the third night (Figure 15). This rapid return to background level on the third night was likely due to the high initial background concentrations observed that night.

The instream DO concentration in Reach 10-11 returned to background concentration at approximately 1200 m downstream of the injection point (Figure 16). The instream DO concentration in Reach 11-12 returned to background concentration at approximately 1400 m on all three nights (Figure 17).

Results from the DOMOD3 model simulation are shown in Figures 15-17. It can be seen from these figures that the model reproduced the observed trends extremely well. Table 2 shows the model parameters used in the simulation runs. The respiration (R), photosynthesis (P) and reaeration ( $K_2$ ) rates are typical of shallow, eutrophic streams. As represented in the model, the combination of respiration and reaeration was sufficient to drive the instream oxygen concentration down and to keep the instream DO concentration from going anoxic once oxygenation ceased.<sup>3</sup>

Table 3 gives a summary of DOMOD3 simulated oxygen injection results using a range of injection levels. Even with an elevated DO level of 8.0 mg/L, the DO returned to the target level of 4.0 mg/L before the end of Reach 9-10. For the other two reaches, once the oxygen concentration was elevated above 5.0 mg/L, it remained above the target level throughout the length of the reach.

3. Willson, K., "Avon River Instream Water Quality Modelling", Stratford/Avon River Environmental Management Project Report Series, No. S-9, January 1983, Draft.

TABLE 2: DOMOD3 MODEL PARAMETERS

DATE	REACH	TOT	Kr	Kd	Kn	R	P	K <sub>2</sub>	Lo	No
JULY										
21/22	9-10	0.32	0.47	0.47	0.1	32	42	5	3.63	4.41
22/23	9-10	0.46	0.47	0.47	0.1	32	42	7.5	3.63	4.41
23/24	9-10	0.30	0.47	0.47	0.1	32	42	5	3.63	4.41
23/24	10-11	0.22	0.27	0.27	0.075	39	54	7	3.04	4.04
21/22	11-12	0.13	0.27	0.27	0.1	30	50	10	2.83	3.96
22/23	11-12	0.22	0.27	0.27	0.1	30	50	14	2.83	3.96
23/24	11-12	0.14	0.27	0.27	0.1	30	50	5	2.83	3.96

TOT: Time of Travel (Days)

Kr : Overall Removal Rate Constant of Carbonaceous Biochemical Oxygen Demand (Day<sup>-1</sup>)

Kd : Deoxygenation Rate Constant due to Carbonaceous Biochemical Oxygen Demand (Day<sup>-1</sup>)

Kn : Deoxygenation Rate Constant due to Nitrogenous Oxygen Demand (Day<sup>-1</sup>)

R : Respiration Rate due to Aquatic Plants (mg O<sub>2</sub> L<sup>-1</sup> Day<sup>-1</sup>)

P : Production Rate due to Aquatic Plants (mg O<sub>2</sub> L<sup>-1</sup> Day<sup>-1</sup>)

K<sub>2</sub> : Atmospheric Reaeration Rate (Day<sup>-1</sup>)

Lo : Ultimate Carbonaceous Oxygen Demand (mg/L)

No : Ultimate Nitrogenous Oxygen Demand (mg/L)

Cs : Oxygen Saturation Concentration at 19.5° C = 9.26 (mg/L)

TABLE 3: SUMMARY OF SIMULATED INJECTION RESULTS

Reach	Background DO before Oxygenation (mg/L)	Injection Level (mg/L)	Background DO after Oxygenation (mg/L)	Longitudinal Extent of Oxygenation to 4 mg/L (m)	Reach Length (m)
9-10	2.0	5.0	0.8	797	3074
	2.0	6.0	0.8	1604	
	2.0	7.0	0.8	2401	
	2.0	8.0	0.8	2401	
10-11	2.0	5.0	0.8	1737	2288
	2.0	6.0	0.8	Stayed above 4.0 mg/L to the end of Reach	
	2.0	7.0	0.8	Stayed above 4.0 mg/L to the end of Reach	
	2.0	8.0	0.8	Stayed above 4.0 mg/L to the end of Reach	
11-12	2.0	5.0	0.8	1500	1615
	2.0	6.0	0.8	Stayed above 4.0 mg/L to the end of Reach	
	2.0	7.0	0.8	Stayed above 4.0 mg/L to the end of Reach	
	2.0	8.0	0.8	Stayed above 4.0 mg/L to the end of Reach	

## 5. DISCUSSION AND CONCLUSIONS

Poor antecedent environmental conditions (low temperatures, cloudy weather, and rainfall) prior to the injection period resulted in little biomass growth and hence low respiration rates in the study stretch. Combined with this, low night-time air temperatures resulted in higher-than-hoped-for night-time deficits. Rather than attempt rescheduling, the experiment was redesigned so that injection commenced whenever DO levels appeared to be at a minimum. It was, however, necessary that injection begin before 2:00 am to allow for establishment of equilibrium before sunrise. Initial DO concentrations were closer to saturation than were hoped for. Some researchers have found that the closer the ambient conditions are to saturation, the lower the solubility of oxygen in water (José Goldman, Canox; personal communication). This condition results in poor injection efficiency and therefore a smaller difference between background and peak elevation.

Difficulties experienced with instrument malfunctioning prevented the presentation of complete diurnal cycles in this report (Figures 15-17). Data obtained during the experimental periods were reliable due to the fact that crews were located at the injection stations to maintain equipment calibration and operation. Left unattended, the instruments frequently tended to drift off calibration.

Unfortunately, all three mid-reach instruments malfunctioned so there were no DO data from these sites to verify the data collected during the longitudinal DO profile monitoring carried out by the crews at 100 m intervals.

Results indicate that the beneficial impact of oxygen injection ranges from 800 m to 1400 m downstream of the injection point. Full-scale application of this technique would require 18 permanent installations (if an average impact length of 1000 m is assumed), in order to maintain a DO level above the Provincial Water Quality Objective (4.0 mg/L) for the Avon River below the Stratford WPCP. It might be necessary to install more than 18 injection units if the oxygen demand in the Avon River was greater than that at the time the experiment was

carried out; a greater demand would result in a shorter longitudinal extent of beneficial effects. However, it may not even be feasible to install all 18 units because of access problems and insufficient water depth. Permanent installations require easy road access for maintenance and oxygen delivery. The capital cost of one installation is estimated at \$18,900 (1982 dollars) and operating and maintenance cost at \$1,419 per month for 5 months per year. These cost estimates include land acquisition, equipment purchases, and delivery and upkeep of the oxygen supply by an external contractor (see appendix for detailed breakdown of costs). This option for improving dissolved oxygen is compared to others in the SAREMP final report.<sup>4</sup>

In summary, this experiment demonstrates that it is possible (although perhaps not always economically feasible) to supplement sagging instream DO levels using the high pressure side-stream technique. The experiment also demonstrates that the beneficial impact of oxygen injection are highly reach specific and depend on the physical, chemical and biologic characteristics of the stream. For another river system with a different set of characteristics (P, R,  $K_2$ , etc.), this technique could yield different results.

4. "Final Report", Stratford/Avon River Environmental Management Project, March 1983, Draft.

## A P P E N D I X

## DETAILED COST ESTIMATE OF ONE INSTALLATION

### Capital Costs

Housing and Land	\$ 9,000
VITOX oxygenation system including electrical panel, DO meter, O <sub>2</sub> flow control, Venturi and dual cyclinder manifold	6,100
(See proposal as per below and design of a permanent oxygen injection system (Figure A1) as supplied by CANOX).	
Electric Pump - 4.5 HP	3,300
Piping and fittings	<u>500</u>
	\$18,900

### Operating and Maintenance Cost

Oxygen supply (200 SCFH x 5 hrs/day x 30 days/month)	\$ 1,175
Facility charges	124
Labour charges (Technician)	<u>120</u>
	\$ 1,419

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PROPOSAL

for a

"VITOX" OXYGENATION SYSTEM

DESCRIPTION OF THE EQUIPMENT AND COSTS

1. Electrical Control Panel

Control Box NEMA 12 with:

- main switch
- 3 control relays
- 1 control timer 0-180s
- 4 control lights
- two 6-digit non-resettable hour totalizers
- 3 test buttons
- 1 pump selector switch
- 7 day, 24 hour timer for automatic o-/off

All wired to terminal block for external wiring  
to pump, oxygen solenoid, oxygen controller,  
pressure switch and 15v/60 Hz supply.

Total            \$1,270.00

2. Dissolved Oxygen System

A. Beckman Analyser

- |  |            |
|--|------------|
| a. Beckman Model 7002 Dissolved Oxygen Analyser  | \$1,565.00 |
| Range: 0 to 2/10/20 P.P.M.                       |            |
| Output: Potentiometric                           |            |
| Power: 117V.A.C. 60 Ht.                          |            |
| C.S.A. Approved                                  |            |
| b. Alarm Kit - fully adjustable high and low     | 397.00     |
| level alarm                                      |            |
| c. Dissolved Oxygen Sensor Configuration #639901 | 635.00     |
| d. 100 ft. of cable, sensor to Model 7002        | 180.00     |
| P/N 193662X                                      |            |

Total            \$2,777.00

**DIVISION OF CANADIAN OXYGEN LIMITED**

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February 11, 1982

2. Dissolved Oxygen System (cont.d)

- B. Kent EIL Oxygen Analyser (Option for Item 2-A)  
Model 9440 DO<sub>2</sub> Indicator, Controller, Transmitter  
with isolated<sup>2</sup> output for recorder with  
Model 9404 DO<sub>2</sub> electrode holder, 3 ft. long  
Model 9441 DO<sub>2</sub> electrode, 100 ft. cabling  
Model 9407-900, Junction Box (temperature  
compensation, integral)

Total            \$2,724.00

3. Oxygen Flow Control/Shut-Off System

Frame-mounted oxygen flow control/shut-off system  
consisting of orifice plate and flanges, oxygen flow  
indicator, control valve, manual shut-off valve,  
solenoid valve for automatic shut-off and non-return  
valve.

Total            \$1,120.00

4. Oxygen "Venturi" Injector

Supplied together with the oxygen storage and  
vaporization equipment on a rental basis.

5. Dual Liquid Cylinder Manifold

Manifold for two cylinders with automatic reserve  
cylinder take-over, complete with flex hoses.

Total            \$ 921.00

6. Oxygen Supply

From the tests carried out in the summer of 1981,  
we trust that the oxygen liquid cylinder is the  
most suitable way of supplying oxygen for this  
application. The liquid cylinders have the  
following specifications:

size:	20 in. diameter x 60 in. high
weight: (empty)	250 lbs.
service pressure (max.)	212 PSIG
capacity - oxygen	4,500 C.F.
gas delivery rate per hour	325 C.F.
oxygen cost	\$3.50/100 C.F. or \$157.50/cylinder FOB pt. of consumption
equipment facility charge	\$62.00/liquid cylinder/month

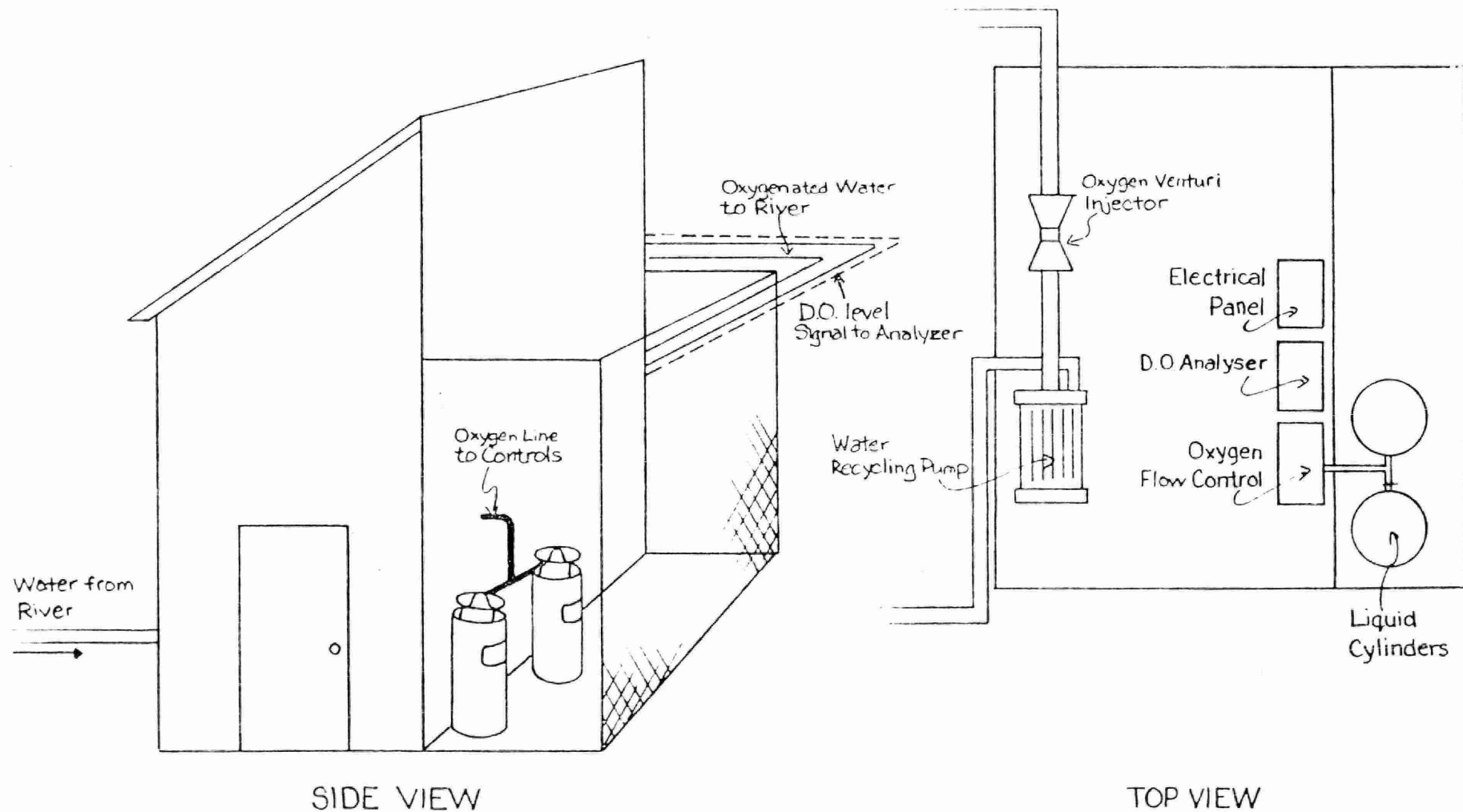
- OBS: 1. For an estimated oxygen consumption of 30,000 SCF/month (200 SCFH X 5 hours/day X 30 days/month injection) the facility charge will be \$124.00/month.
2. The oxygen injection station will operate with two liquid cylinders manifolded together with an automatic system designed to switch over to the full cylinder in case the other has been emptied. Canox will schedule the deliveries and will change the empty cylinders in an adequate way to suit the operation.
3. Dissolved Oxygen Analyser to be purchased directly from recommended suppliers or representatives.

N.B. The prices quoted above apply until May 15, 1982.

Fig. A1: DESIGN OF A PERMANENT OXYGEN INJECTION SYSTEM



## CONTROL AND PUMPING HOUSE



STRATFORD-AVON RIVER ENVIRONMENTAL MANAGEMENT PROJECT  
LIST OF TECHNICAL REPORTS

- S-1 Impact of Stratford City Impoundments on Water Quality in the Avon River
- S-2 Physical Characteristics of the Avon River
- S-3 Water Quality Monitoring of the Avon River - 1980, 1981
- S-4 Experimental Efforts to Inject Pure Oxygen into the Avon River
- S-5 Experimental Efforts to Aerate the Avon River with Small Instream Dams
- S-6 Growth of Aquatic Plants in the Avon River
- S-7 Alternative Methods of Reducing Aquatic Plant Growth in the Avon River
- S-8 Dispersion of the Stratford Sewage Treatment Plant Effluent into the Avon River
- S-9 Avon River Instream Water Quality Modelling
- S-10 Fisheries of the Avon River
- S-11 Comparison of Avon River Water Quality During Wet and Dry Weather Conditions
- S-12 Phosphorus Bioavailability of the Avon River
- S-13 A Feasibility Study for Augmenting Avon River Flow by Ground Water
- S-14 Experiments to Control Aquatic Plant Growth by Shading
- S-15 Design of an Arboreal Shade Project to Control Aquatic Plant Growth
  
- U-1 Urban Pollution Control Strategy for Stratford, Ontario - An Overview
- U-2 Inflow/Infiltration Isolation Analysis
- U-3 Characterization of Urban Dry Weather Loadings
- U-4 Advanced Phosphorus Control at the Stratford WPCP
- U-5 Municipal Experience in Inflow Control Through Removal of Household Roof Leaders
- U-6 Analysis and Control of Wet Weather Sanitary Flows
- U-7 Characterization and Control of Urban Runoff
- U-8 Analysis of Disinfection Alternatives
  
- R-1 Agricultural Impacts on the Avon River - An Overview
- R-2 Earth Berms and Drop Inlet Structures
- R-3 Demonstration of Improved Livestock and Manure Management Techniques in a Swine operation
- R-4 Identification of Priority Management Areas in the Avon River
- R-5 Occurrence and Control of Soil Erosion and Fluvial Sedimentation in Selected Basins of the Thames River Watershed
- R-6 Open Drain Improvement
- R-7 Grassed Waterway Demonstration Projects
- R-8 The Controlled Access of Livestock to Open Water Courses
- R-9 Physical Characteristics and Land Uses of the Avon River Drainage Basin
- R-10 Stripcropping Demonstration Project
- R-11 Water Quality Monitoring of Agricultural Diffuse Sources
- R-12 Comparative Tillage Trials
- R-13 Sediment Basin Demonstration Project
- R-14 Evaluation of Tillage Demonstration Using Sediment Traps
- R-15 Statistical Modelling of Instream Phosphorus
- R-16 Gully Erosion Control Demonstration Project
- R-17 Institutional Framework for the Control of Diffuse Agricultural Sources of Water Pollution
- R-18 Cropping-Income Impacts of Management Measures to Control Soil Loss
- R-19 An Intensive Water Quality Survey of Stream Cattle Access Sites



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